

# **Northeastern California Ethanol Manufacturing Feasibility Study**

*Prepared by:*

**Quincy Library Group**

**California Energy Commission**

**California Institute of Food and Agricultural Research**

**Plumas Corporation**

**TSS Consultants**

**National Renewable Energy Laboratory**

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## EXECUTIVE SUMMARY

The State of California is faced with several critical issues related to how its biomass resources are used and managed. In particular, due to suppression of forest fires, large quantities of dead/diseased trees and underbrush have accumulated in the forest, creating dangerous fuel loading which threatens human life and property. Resulting fires are so intense that they destroy the forest ecosystem. In addition, the unnatural ecosystem produced by fire suppression is endangering forest health.

To deal with these issues, the Quincy Library Group has put forth a plan to strategically thin the forests so as to reduce fire danger, improve forest health, and restore ecosystem balance. However, a key question is what will be done with the smaller trees (both live and dead) once they are removed from the forests. This report presents the results of one potential use of the biomass — conversion to fuel ethanol and cogenerated electricity. This option has appeal in that the technology for ethanol production from biomass is ready for demonstration and the demand for fuel oxygenates, such as ethanol and ETBE, is growing in California. In addition, there are synergistic benefits to the existing biomass-electricity industry. Finally, the technology is ecologically sound.

The Quincy Library Group (QLG), with the assistance of the California Resources Agency, assembled a very capable project team with the expertise needed to successfully carry out the feasibility study. The project was directed by the Quincy Library Group with assistance from the National Renewable Energy Laboratory (NREL). The following companies, organizations and agencies have contributed their time, effort and financial support to the Northeastern California Ethanol Manufacturing Feasibility Study:

Arkenol, Inc.,  
Biomass Processors Association,  
CA Air Resources Board,  
CA Department of Forestry and Fire Protection,  
CA Department of Food and Agriculture,  
CA Department of Water Resources,  
CA Energy Commission,  
CA Integrated Waste Management Board,  
CA Resources Agency,  
CA Institute of Food and Agricultural Research (CIFAR),  
City of Anderson,  
Collins Pine Company,  
DOE Office of Fuels Development,

Grant & Resource Center of Northern CA,  
HFTA/University of California Forest Products Lab,  
High Sierra Resource Conservation Development Area,  
James Irvine Foundation,  
Lead Partnership Group,  
National Renewable Energy Laboratory,  
Pacific Wood Fuels,  
Plumas Corporation,  
Sierra Economic Development District,  
Sierra Pacific Industries,  
TSS Consultants,  
USDA Forest Service (Lassen, Tahoe, and Plumas National Forests).

Each project task is summarized below. Additional details can be found in the report following the Executive Summary.

### ***Feedstock Supply and Delivery Systems***

TSS Consultants concluded that there is adequate biomass available in the QLG area for one or more biomass to ethanol and power facilities. The study area includes most of the Lassen and Plumas National Forests and the Sierraville Ranger District of the Tahoe National Forest. The amount of biomass available at each site within the QLG study area is shown in Table ES-1. The amount of biomass available ranges from 186,880 bone dry tons (BDT) within a 25-mile radius of Loyalton to 335,716 BDT within a 25 mile radius of Greenville.

**Table ES-1. 25-Mile Radius Biomass Feedstock Availability**

<b>Site</b>	<b>Fuel treatment (BDT/Year)</b>	<b>Timber harvest (BDT/Year)</b>	<b>Total Feedstock (BDT/Year)</b>
Loyalton	64,773	122,107	186,880
Chester	54,822	212,905	267,727
Westwood	87,801	182,671	270,472
Greenville	99,261	236,455	335,716

Anderson and Martell were not included in the feedstock study, but it is assumed that adequate supplies exist in those areas also. With the closure of several biomass power plants in the last several years, there is currently an oversupply of biomass available in California.

### ***Site Characterization***

The California Energy Commission's Energy Facilities Siting & Environmental Protection Division conducted a site characterization study of the six sites identified for the feasibility study (see Figure ES-1). The proposed sites are associated with existing or former sawmill sites located in the towns of Anderson, Chester, Greenville, Loyalton, Martell, and Westwood. All of the sites with the exception of Greenville, have access to existing biomass power plants, and all are large enough to accommodate a new biomass to ethanol facility with associated feedstock storage. While all the sites appear to be feasible sites for the project, the Greenville site has the most constraints. This is because it does not have an existing power plant or biomass facility. Development of this site would bear the highest cost and cause the greatest change to the environment at the site.

### ***Ethanol Facility Design and Cost Estimate***

NREL prepared design and cost estimates for each of the six study sites and three different biomass to ethanol conversion technologies. The conversion technologies included in the study are by no means the only technology options, but are a good representation of the near-term opportunities. The technologies considered in this report are:



- concentrated sulfuric acid (includes technology patented by Arkenol, Inc.)
- dilute sulfuric acid (contains no patented technology)
- dilute nitric acid (includes technology with licensing available from HFTA)

**Many assumptions enter into the design and economic analyses presented in this report and the reader is warned that additional investigations and testing are strongly recommended before selecting a biomass to ethanol conversion technology.** The major areas of concern with respect to the biomass to ethanol process design and technology performance parameters are discussed at the end of each of the three technology sections of the *Biomass to Ethanol Facility Design, Cost Estimate, and Financial Evaluation* report.

The size of the ethanol facility at each site is based on the amount of feedstock available within a 25-mile radius of the site according to the feedstock assessment report plus mill residue that may be available at the site. The resulting ethanol plant sizes range from 11.8 million gallons per year at the Loyalton site (with dilute acid technology) to 28.2 million gallons per year at the Greenville site (with concentrated acid technology).

### ***Economic Analysis***

Internal rate of return (IRR) was calculated for each technology at each site resulting in 18 combinations of technologies and sites (Table ES-2). A 20-year project life, 100% owner equity, a feedstock cost of \$20 per BDT, and an ethanol selling price of \$1.20 per gallon was assumed to calculate the IRRs. Additional financial assumptions are included in the report.

**Table ES-2. Internal Rate of Return (IRR) for 100% Owner Equity**

<b>Site</b>	<b>Concentrated Acid</b>	<b>Dilute Sulfuric Acid</b>	<b>Dilute Nitric Acid</b>
Anderson	5%	5%	11%
Chester	7%	5%	11%
Greenville	4%	-3%	3%
Loyalton	5%	2%	9%
Martell	6%	4%	10%
Westwood	6%	4%	10%

Projects of this magnitude are rarely financed with 100% owner equity. It is well known that favorable financing terms can be used to leverage the owner's equity and dramatically improve the IRR. A scenario

with 25% owner equity and 75% debt financing was evaluated (Table ES-3). A loan interest rate of 7% and a 10 year loan term was chosen to represent perhaps the best possible financing scenario. A 7% interest rate loan may be available through the new electric utility restructuring Public Interest Energy Research (PIER) Program (to be administered by the California Energy Commission), through the California Pollution Control Financing Authority.

**Table ES-3. Internal Rate of Return (IRR) for 25% Owner Equity**

Site	Concentrated Acid	Dilute Sulfuric Acid	Dilute Nitric Acid
Anderson	8%	9%	25%
Chester	15%	9%	25%
Greenville	7%	-4%	6%
Loyalton	9%	4%	18%
Martell	12%	7%	22%
Westwood	12%	7%	23%

### *Sensitivity Analysis*

The sensitivity of project profitability (as measured by IRR) to the variables listed in Table ES-4 was evaluated. The results indicate that the IRR is most sensitive to feedstock cost and owner equity. Ethanol plant size, annual manufacturing cost, ethanol selling price, ethanol facility capital cost, and feedstock composition all display moderate sensitivities. A 30% increase or decrease in direct labor cost has relatively little effect on the IRR.

**Table ES-4. Summary of sensitivities for Chester site and dilute nitric acid process.**

Sensitivity Variable and Rank - High to Low	Sensitivity Range	Corresponding IRR Range (Ä%)
1. Delivered feedstock cost	\$38 - \$0 per BDT feedstock	1% to 44% (43%)
2. Owner equity	100% to 5% equity	11% to 50% (39%)
3. Ethanol plant size	6 - 19 million gal. ethanol/year	0% to 31% (31%)
4. Annual manufacturing cost	+/- 20% of manufacturing cost	9% to 38% (29%)

5. Ethanol selling price	\$1.00 - \$1.40 per gal. ethanol	11% to 36% (25%)
6. Ethanol facility capital cost	+/- 30% of capital cost	17% to 37% (20%)
7. Feedstock composition	33 - 53% glucan in feedstock	14% to 34% (20%)
8. Annual direct labor cost	+/- 30% of direct labor cost	23% to 28% (5%)

### ***Environmental Issues***

The potential environmental effects of operating a commercial-scale biomass-to-ethanol plant include both the on-site and off-site impacts surrounding the production facility.

The on-site environmental impacts (as well as local community impacts) are discussed in the site- specific evaluations conducted by the California Energy Commission in the *Site Characterization Study* issued in April 1997. The CEC study reviewed various environmental and infrastructure factors at the six study sites in Northeastern California.

Cellulose biomass material will be generated from both public and private forest lands within at least a 25-mile radius of the ethanol facility. TSS Consultants' *Feedstock Supply and Delivery Systems* report (June 1997) predicts an available and sustainable, annual supply of between 187,000 and 336,000 Bone Dry Tons (BDT), dependent upon site. Sources of biomass will be timber harvesting by-products, certain lumber mill residues as well as forest fuels reduction treatments. The same report, using the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection, defined that USFS holdings (within 25 miles of the four QLG sites) ranged between 53% to 64%. This includes all lands, not just forested lands. Federally managed forest lands are expected to be a higher percentage.

Environmental reviews and public participation processes that are prerequisites for authorizing biomass harvest differ between land ownership types. On private timberlands, California Forest Practice Rules govern timber harvest practices. Biomass harvest activities on National Forest System lands - the presumed primary source for any ethanol facility within the Quincy Library Group's area of interest since the majority of the forest lands are federally administered - must be subjected to National Environmental Policy Act (NEPA) reviews and public participation processes of the U.S. Forest Service. Projects on federal lands must also have the environmental review conducted within the current regional or national context, which must take into account the "latest science."

The plan proposed by the QLG intentionally reduces the environmental impacts of the large scale- thinning program that is proposed (>50,000 acres per year for five years) through adoption of various measures on US Forest Service lands designed to reduce those impacts. These measures include:

- Use of the Scientific Assessment Team (SAT) riparian standards for timber harvest activities, which



typically preclude timber harvest within two "site tree" lengths of a perennial stream;

- Precluding timber harvests on the primary old growth and anadromous fish stream areas of the forest by defining those areas as "Off-Base" or "Deferred" from timber harvests;
- Adoption of the California Spotted Owl guidelines (1993), which preclude trees over 30 " from harvesting as well as limit basal area and tree canopy reductions from thinning programs; and
- Precluding timber harvests in so-called "Spotted Owl Protected Activity Centers" (PACs) and "Spotted Owl Habitat Areas" (SOHAs).

The typical environmental concerns that arise from timber harvest and biomass harvest activities include the effects of roads and landings, riparian zone and water quality impacts, fuel loadings and arrangements, wildlife disturbances, and changes in suitability of wildlife habitats. Generically, these can be grouped into soil, water and wildlife impacts. The Plumas, Lassen, and Tahoe National Forest Plans have standards and guidelines applicable to the protection of soil, water, and wildlife resources and the USFS region has adopted a series of best management practices (BMPs).

Monitoring the results of biomass harvest will be critical to the overall success of the biomass removal program. The Quincy Library Group calls for an active and comprehensive monitoring program at various temporal and landscape scales. The USDA Forest Service has received funds from the Secretary of Agriculture, as part of the USDA support of the Quincy Library Group proposal, to develop and implement these monitoring programs. The QLG bills call for a "science based assessment."

The monitoring plan is designed to answer a series of questions:

- Implementation

Are projects implemented as designed?

- Effectiveness at Site Scale

Are soil quality standards met?

What are the impacts in streamside zones?

Are BMPs implemented/effective?

Is fire behavior modified?

How is vegetation modified in short term and long term?

How are fuels modified in short term and long term?

How is terrestrial habitat modified in short and long term?

Are watershed restoration projects effective?

Are Hypogeous fungi modified?

What are air quality effects of controlled burns?

- Larger Scale Effects

Is aquatic habitat improved?

What are vegetation trends?

What are size and intensity of wildfire trends?

### ***Market Issues***

Ethanol demand in the western states of California, Arizona, Nevada, Oregon and Washington increased from 154 million to 214 million gallons per year from 1992 to 1995. In 1996, ethanol demand dropped to 124 million gallons per year with the loss of the California market and a significant decrease in the Washington market. Ethanol demand is driven primarily by federal and state Clean Air Act requirements mandating the use of oxygenates in winter gasoline to lower carbon monoxide emissions. The annual gasoline demand, required oxygenate level in the state's RFG or winter gasoline, and the estimated winter oxygenate season ethanol sales for 1992 through 1997 are shown in Table ES-5 below.

**Table ES-5. Historical West Coast Ethanol Demand (1992 through 1997).**

<b>State</b>	<b>Annual Gasoline Demand (1000 gal)</b>	<b>Oxy Level (% by wt.)</b>	<b>Ethanol Est. sales 92-93 (1000 gal)</b>	<b>Ethanol Est. sales 93-94 (1000 gal)</b>	<b>Ethanol Est. sales 94-95 (1000 gal)</b>	<b>Ethanol Est. sales 95-96 (1000 gal)</b>	<b>Ethanol Est. sales 96-97 (1000 gal)</b>
CA	13,000,000	2.0	50,000	50,000	50,000	50,000	0
AZ	1,800,000	2.7	9,300	15,500	46,500	62,000	62,000
NV	750,000	3.5	4,900	9,750	18,000	26,750	29,000
WA	2,400,000	2.7	60,000	60,000	50,000	50,000	7,500
OR	1,500,000	2.7	30,000	25,000	25,000	25,000	25,000
<b>Totals</b>	<b>19,450,000</b>		<b>154,200</b>	<b>160,250</b>	<b>189,500</b>	<b>213,750</b>	<b>123,500</b>

Current ethanol production capacity on the west coast is only 14 million gallons per year— approximately 6 million gallons per year is produced in California and 8 million gallons per year in Washington. The remainder is imported from the midwest. Production of ethanol in California would result in significantly

lower transportation costs to the west coast ethanol markets providing an advantage for projects such as a biomass to ethanol project in the QLG area. California ethanol producers could have up to a \$0.20 per gallon cost advantage over midwest producers due to transportation costs.

Ethanol pricing is impacted by variables such as corn prices, MTBE prices, gasoline prices, and clean air act regulations. In the last five years, wholesale delivered prices to western ethanol markets have ranged between \$1.18 and \$1.55 per gallon. Given the seasonal nature of the demand, winter prices tend to be significantly higher than summer prices. 1996 was an exceptional year due to historically high corn prices resulting in high ethanol prices throughout the year. In 1997, ethanol prices have returned to traditional levels of \$1.25 to \$1.30 per gallon.

The current market for California ethanol is outside of California due to the policy issues discussed in the report. The current west coast market is approximately 125 million gallons of ethanol per year. California ethanol should enjoy a cost advantage due to significantly lower transportation costs compared to ethanol produced in the Midwest. The west coast ethanol market is projected to parallel the growth of the U.S. ethanol market at 3% per year.

The west coast ethanol market could expand dramatically if the California RFG market becomes available to ethanol. California legislation or policy changes could create a market potential of 750 million gallons per year for ethanol produced in California and utilized as E10 in existing vehicles. The wide spread use of flexible fuel vehicles and alternative fuel buses utilizing E85 (85% ethanol blended with 15% gasoline) could increase this amount. Feedstock availability limitations and resultant feedstock cost growth could impact the economics and reduce the rate of market penetration. Energy crops could become economic and contribute to additional growth.

### ***Socioeconomic Issues***

The socioeconomic report, prepared by Plumas Corporation and QLG, reviews the local, regional and statewide implications of building and operating a forest biomass to ethanol manufacturing facility at specified sites in the Quincy Library Group area (Lassen, Plumas and Sierra counties in the Sierra Nevada) or other sites in Northern California. The report first sets the current socioeconomic context in this natural resource dependent area. It then reviews the effect of an ethanol plant on employment, personal incomes, state and local taxes, construction jobs, and local infrastructure (particularly roads, schools and utilities). It also reviews the implications of such a facility in Amador or Shasta County.

A modest sized forest biomass to ethanol demonstration plant (e.g. producing 15 million gallons per year) will create at least 28 direct jobs at the plant, if it is co-located with an existing biomass electricity energy plant. Additional jobs would be created if a biomass electric energy plant was built along with the ethanol manufacturing facility. The furnishing of forest biomass feedstock to this plant would employ 63-100 additional employees to gather, process and transport the cellulose material to the plant. These 91-128 direct jobs would be augmented by an additional 93-122 indirect or multiplier jobs. One 15 million gallon per year ethanol plant would thus generate between 184-250 total jobs.

The total direct payroll for the ethanol facility and the feedstock collection, processing and transportation is estimated to be \$2,623,080. Total direct and indirect payroll is estimated to be \$4,884,240. Construction jobs are estimated at 88 jobs with a payroll of approximately \$2,000,000.

## ***Feasibility Study Conclusions and Recommendations***

Conversion of forest thinnings and timber harvest residues to ethanol and cogenerated electricity appears to be economically feasible at the five sites in the study that have an existing biomass power plant and other infrastructure available. Colocation with an existing biomass power plant is essential at this time.

The undeveloped or "greenfield" site in Greenville requires the installation of a boiler to provide steam to the ethanol process as well as buildings and other infrastructure that adds significantly to the total capital cost making this site less appealing at this time.

There appears to be an adequate supply of feedstock for one or more biomass to ethanol facilities in the Quincy feasibility study area.

The California reformulated gas (CA RFG) market is potentially a huge market for ethanol or ETBE at almost 1 billion gallons of oxygenate per year. However, ethanol is not currently used in California due to the 2% cap on oxygen in CA RFG. Other West Coast markets, although much smaller than the California market, are still significant and estimated to be approximately 125 million gallons ethanol per year.

Forest biomass can be removed from the forest with acceptable impact to the environment and thinning the forest in the study area will improve the overall forest health and ecosystem balance.

Many technical, economic, and other assumptions have been made to perform the analyses reported in this study. Additional work is needed to prove or disprove these assumption and reduce the uncertainty of the results. The following *next steps* are recommended:

- Identify Potential Owner/Operators

Quincy Library Group will identify potential owners/operators of the ethanol manufacturing facility. This will entail reviewing the feasibility study with the current site owners to determine whether this project would fit into their own development plans. This task will also consist of discussions with current operators of ethanol manufacturing facilities (as well as other operators) to determine whether this new feedstock source (forest biomass) fits with their expansion plans.

- Secure Site Commitments

Quincy Library Group will solicit Letters of Intent from the site owners in this feasibility report (by the end of 1997) to quantify and qualify the general terms and conditions under which they would enter into the development phase of the project. QLG and NREL will also begin introducing prospective operators to the site owners and to ethanol technology purveyors.

- Long Term Supply Agreements

The delivered feedstock supply and price are the most sensitive economic factors in the feasibility study. QLG will investigate specific opportunities and seek the development of long term agreements on both public (particularly USDA Forest Service) and private lands.

- Design and Cost Estimates

A variety of further engineering and design tasks were identified for each of the three technologies studied. NREL will pursue partnerships and funding for these subsequent tasks.

## **Report Structure/Organization**

The remainder of this report is organized as follows. The *Introduction* discusses the major issues and project objectives, and introduces the project participants. The seven major tasks are then summarized so that the reader can get an overview of the project scope and results without reading all of the individual task reports. If the reader needs more information on a particular task, the task report can then be consulted. Conclusion and recommendations follow the task summary section. This is then followed by the complete task reports.

If you have downloaded the *Executive Summary* from the Internet and would like a copy of the complete report or any of the individual task reports, please contact Sally Neufeld or Mark Yancey of the National Renewable Energy Laboratory at (303) 275-3000.

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## I. INTRODUCTION

People have intervened in California's forest ecosystems since before recorded history, but during the past hundred years the interventions have changed radically in nature. Due to California's geography and climate, fire has always been a factor in California's forests. Around the turn of the century, California began a major and long-term commitment to suppressing fires in the state's forests, with great success. One of the most significant, unexpected results of the forest fire fighting efforts has been a long-term build-up of biomass in the forests, which causes a variety of undesirable consequences:

- The extent and severity of forest fires in overstocked forests is much greater than in the native ecosystem environment, turning fires with positive ecosystem functions into infernos that destroy everything in vast areas.
- High densities of growing stock prevent the growth of healthy, high-quality, individual trees, and diminish the wildlife habitat of the forest.
- Overstocking of biomass in the forest increases evapotranspiration, and diminishes the amount of ground water available for summer runoff, as compared with the native forest ecosystem.

In the absence of energy markets or other beneficial uses, most in-forest residues are left in place in the forest. Both the California Department of Forestry, and the USDA Forest Service, recognize this as a major impediment to maintaining forest health in California. These agencies also see the consequences of fuel loading on their fire fighting budgets, which have sky-rocketed in recent years. The cheapest means of reducing the fuel loading problem in the forests is prescribed burns, and both state and federal forest managers are carrying out limited burns in order to reduce the problem. The amount of prescribed burning that is allowed, however, is limited due to environmental concerns. Harvesting, processing, and transporting the material to biomass power plants is more expensive, but provides a beneficial use for the material, and virtually eliminates the pollution associated with open burning. The amount of forest biomass that can be utilized by the biomass power industry is limited and is not adequate for the large volumes of biomass to be removed from California's forests.

Converting forest biomass to ethanol may be a beneficial use that can utilize all of the biomass that needs to be removed from California's forests. The reason for this is that ethanol is a higher value product than electricity produced from biomass, and ethanol can be used in the huge California transportation fuels market. If ethanol were blended in 80% of California's reformulated gasoline, ethanol use in California would be almost 800 million gallons per year<sup>1</sup>. Thinning just 2% of California's 16 million acres of commercial forests<sup>2</sup> each year and converting the biomass to ethanol would produce 226 million gallons of

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<sup>1</sup> SWAN Biomass Company, *Ethanol Market Assessment*, Dowers Grove, IL, 1997.

<sup>2</sup> Western Wood Products Association, 1992 data.



ethanol, 28% of the maximum potential ethanol market in the state<sup>3</sup>.

Forestry officials would like to see large areas of California's forests thinned over the next several years and decades. The USDA Forest Service, which manages approximately one-half of the state's forest land, states that at least 250,000 acres per year of the land under their jurisdiction needs to be thinned in order to fully realize the fire suppression, forest health, and water yield increases that are desirable<sup>4</sup>.

To deal with these issues, the Quincy Library Group has put forth a plan to strategically thin the forests so as to reduce fire danger, improve forest health, and restore ecosystem balance. However, a key question is what will be done with the smaller trees once they are removed from the forests. This report presents the results of one potential use of the biomass — conversion to fuel ethanol and cogenerated electricity. This option has appeal in that the technology for ethanol production from biomass is ready for demonstration and the demand for fuel oxygenates, such as ethanol and ETBE, is growing in California. In addition, there are synergistic benefits to the existing biomass-electricity industry. Finally, the technology is ecologically sound.

## **II. PROJECT OBJECTIVES & PROJECT TEAM**

### ***Project Objective***

The objective of this project is to determine the economic, environmental and regulatory feasibility of siting one or more forest biomass to ethanol manufacturing facilities in Northeastern California. The study area includes most of the Lassen and Plumas National Forests and the Sierraville Ranger District of the Tahoe National Forest. The study will identify and evaluate several sites in the study area which have the greatest potential for long-term operation of a financially attractive biomass-to-ethanol production facility. The effort will evaluate biomass supply as well as ethanol and power generation market issues which could impact the long term viability of the facilities. Several biomass conversion process options will be evaluated from both a technical and economic perspective as well.

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<sup>3</sup> Assumptions include 10 BDT biomass yield per acre and 87 gallons ethanol produced per BDT biomass (concentrated acid technology ethanol yield).

<sup>4</sup> Morris, G., *The Environmental Costs and Benefits of Biomass Energy Use in California*, Berkeley, CA, 1997.

### ***Project Team***

The Quincy Library Group (QLG), with the assistance of the California Resources Agency, assembled a very capable project team with the expertise needed to successfully carry out the feasibility study. The project was directed by the Quincy Library Group with assistance from the National Renewable Energy Laboratory (NREL). The following companies, organizations and agencies have contributed their time, effort and financial support to the Northeastern California Ethanol Manufacturing Feasibility Study:

Arkenol, Inc.,	Grant & Resource Center of Northern CA,
Biomass Processors Association,	HFTA/University of California Forest Products
CA Air Resources Board,	Lab,
CA Department of Forestry and Fire Protection,	High Sierra Resource Conservation
CA Department of Food and Agriculture,	Development Area,
CA Department of Water Resources,	James Irvine Foundation,
CA Energy Commission,	Lead Partnership Group,
CA Integrated Waste Management Board,	National Renewable Energy Laboratory,
CA Resources Agency,	Pacific Wood Fuels,
CA Institute of Food and Agricultural Research	Plumas Corporation,
(CIFAR),	Sierra Economic Development District,
City of Anderson,	Sierra Pacific Industries,
Collins Pine Company,	TSS Consultants,
DOE Office of Fuels Development,	USDA Forest Service (Lassen, Tahoe, and
	Plumas National Forests).

### ***Project Task Summary***

The project includes the following seven tasks with the lead organization for each task listed:

- Feedstock supply and delivery systems, TSS Consultants
- Site selection, QLG/Plumas Corporation/CEC
- Ethanol facility design and cost estimate, NREL
- Financial evaluation and sensitivity analysis, NREL
- Environmental and permitting issues, QLG/CEC
- Market issues, CIFAR
- Socioeconomic issues, Plumas Corporation/QLG

The results of each task is summarized in the following *Summary of Tasks* section. The complete task reports are included in the *Task Reports* section which follows the *Conclusions and Recommendations*.

### **III. SUMMARY OF TASKS**

#### ***Feedstock Supply and Delivery Systems***

TSS Consultants (TSS) established the resource and supply system needed to support sustainable ethanol/cogeneration plant operation. Feedstocks, harvesting and delivery requirements were defined and used to establish costs for feedstock that support the economic assessment of the project.

The feedstock supply study area includes most of the Lassen and Plumas National Forests and the Sierraville District of the Tahoe National Forest, which encompasses approximately 2.4 million acres. This forest area has been severely affected by previous drought years and insect infestation, resulting in extensive buildup of biomass fuels. In the study area, one hundred years of fire exclusion and various management activities combine to result in stand conditions which support large stand-replacing fires.

To address these issues, the Quincy Library Group (QLG) put forth a plan to strategically thin the forests to; improve forest health, restore ecosystem balance, and reduce fire danger.

The Quincy Library Group Forest Recovery and Economic Stability Act of 1997 was introduced during the 1<sup>st</sup> Session of the 105<sup>th</sup> Congress. This legislation will direct the Secretary of Agriculture to conduct a five-year pilot project on designated lands within the Plumas, Lassen, and Tahoe National Forests in the State of California to demonstrate the effectiveness of the resource management activities proposed by the Quincy Library Group and to amend current land and resource management plans for these national forests to consider the incorporation of these resource management activities.

TSS is of the opinion that biomass feedstock for the QLG project can be recovered from fuel reduction strategies carried out on national forest lands such as creating Defensible Fuel Profile Zones, Community Defense Zones and Fuel Reduction Zones as well as from collecting and processing biomass from timber harvesting operations.

TSS estimated the quantity of biomass that could be available in the entire QLG project area from fuel treatment activities and from timber harvesting operations. Assuming that the Forest Service conducts the proposed pilot project on designated lands within the Plumas, Lassen, and Tahoe National Forests and that timber harvest levels are equal to the previous 4 years average, TSS estimates that during the period of years 1-5, a total of 1,100,000 BDT will be available annually and during the period of years 6-20, a total of approximately 706,250 BDT annually will be available to the QLG project. The division in projected biomass generation between timber harvest operations and fuel treatment for years 1-5 and 6-20 is shown

in Table 1.

**Table 1. Estimated Biomass Feedstock Generation within the QLG Area**

<b>Biomass Source</b>	<b>Year 1 - 5 (BDT/Year)</b>	<b>Year 6 - 20 (BDT/Year)</b>
Timber harvest operations	475,000	475,000
Fuel treatment	625,000	231,250
<b>Total</b>	<b>1,100,000</b>	<b>706,000</b>

TSS made an assessment of the biomass feedstock that could be available to each of the biomass to ethanol plant sites in the QLG area from a fuel treatment program as well as from collecting and processing biomass from timber harvesting operations. The sites for this assessment were determined to be; Westwood, Chester, Greenville and Loyalton. Estimates of the annual amounts of biomass feedstock available within a 25-mile radius of each site are shown in Table 2. Greenville has the most biomass available within a 25-mile radius, followed by Westwood, Chester, and Loyalton. The year 6-20 fuel treatment biomass generation estimates were used for the site feedstock availability estimates. Note that there is considerable overlap in the 25-mile radius feedstock collection areas for Westwood, Chester, and Greenville.

**Table 2. 25-Mile Radius Biomass Feedstock Availability**

	<b>Fuel treatment</b>	<b>Timber harvest</b>	<b>Total Feedstock</b>
<b>Site</b>	<b>(BDT/Year)</b>	<b>(BDT/Year)</b>	<b>(BDT/Year)</b>
Greenville	99,261	236,455	335,716
Westwood	87,801	182,671	270,472
Chester	54,822	212,905	267,727
Loyalton	64,773	122,107	186,880

Based upon the analysis conducted by TSS, we can conclude that adequate quantities of biomass feedstock are available within the QLG supply area.

Systems for the collection, processing, and transportation of biomass are well established within this area. The estimated total costs for collection, processing and transportation of biomass feedstock to the QLG project is expected to average \$40 per BDT. The cost to the project can be reduced to a range of \$20 to \$25 per BDT by continued and expanded subsidies from the landowner for fuel treatment activities. In addition, many national forest offerings of timber sales or service contracts containing biomass material also have a sufficient amount of sawlogs with sufficient value to effectively subsidize the removal of the biomass at a cost that ranges between \$20 to \$30 per BDT. The total cost of feedstock delivered to the Facility will vary depending upon the amount of subsidy that can be achieved through ongoing programs such as the Forest Health Pilot Program as well as the amount of sawlogs that is offered for sale along with the biomass. The cost of collection and processing (shearing, skidding and chipping) can vary greatly from job to job depending upon factors such as tree size and density, slope of the ground and the size of the project. These costs can range between \$30 to \$40 per BDT, FOB truck.

Transportation costs will vary based upon the distance to the facility, (i.e. the amount of time required as current inforest biomass transportation rates vary from \$50 to \$55 per hour) the quality of the transportation system as well as the cost of maintenance of private or Forest Service roads and the moisture content of the biomass feedstock, which will determine the average number of BDT per load. Transportation costs are expected to range from \$9 to \$20 per BDT.

The ultimate cost of transportation will be related to the size of the biomass to ethanol project, as the size will determine the transportation distance that will be required to supply the project. Future biomass feedstock cost could also vary depending upon the competition for biomass feedstock from other uses during the life of the project.

### ***Site Characterization***

The California Energy Commission's Energy Facilities Siting & Environmental Protection Division (EFS & EPD) provided assistance in selecting a site for a biomass to ethanol facility in Northeastern California. CEC Staff conducted a site characterization study of seven sites (includes two sites at Anderson, CA) identified by the QLG. The sites are associated with existing or former sawmill sites located in the towns of Loyalton, Chester, Greenville, Westwood, Martell, and Anderson.

All of the sites with the exception of Greenville, have access to existing biomass power plants, and all are large enough to accommodate a new biomass to ethanol facility with associated feedstock storage. While all the sites appear to be feasible sites for the project, the Greenville site has the most constraints. This is because it does not have an existing power plant or biomass facility. Development of this site would bear the highest cost and cause the greatest change to the environment at the site.

The six sites included in the feasibility study and the existing infrastructure available at each site are listed in Table 3 below.

**Table 3. Site Data and Infrastructure**

<b>Site, Owner</b>	<b>Biomass Power (gross MW)</b>	<b>Utilities Available</b>	<b>Other Considerations</b>
Anderson, Roseburg Industries	49.9 MW *	Biomass electricity Steam, Water Wastewater treatment	Stand-alone biomass power plant Pulp and paper mill
Chester, Collins Pine Co.	12 MW	Biomass electricity Steam, Water	Lumber mill
Greenville, Carl Pew	no biomass power at this site	Electricity from grid, Water	Former lumber mill site
Loyalton, Sierra Pacific Ind.	20 MW	Biomass electricity Steam, Water	Lumber mill
Martell, Sierra Pacific Ind.	18 MW *	Biomass electricity Steam, Water	Lumber mill (closed)
Westwood, Mt. Lassen Power	13 MW	Biomass electricity Steam, Water	Stand-alone biomass power plant

\* biomass power plant is owned and operated by Wheelabrator Environmental Systems Inc.

### ***Design and Cost Estimate***

NREL examined three different biomass to ethanol conversion technologies and then developed preliminary process designs and performed standard economic analyses for these designs applied to the six sites previously identified for the feasibility study. **Many assumptions enter into the design and economic analyses presented in this report and the reader is warned that additional investigations and testing are strongly recommended before selecting and attempting to commercialize any biomass to ethanol conversion technology.**

**No attempt has been made to rank the technologies evaluated in this report due to the large uncertainties in the process design and process performance, especially with respect to the dilute sulfuric and nitric acid technologies considered. There are also other technologies available that should be considered for biomass to ethanol conversion projects.**

**Likewise, NREL has made no attempt to rank the six sites in the study except to point out that the Greenville site requires significantly more infrastructure development and therefore has a much higher capital cost than the other sites which have biomass power available.**

The study concludes that converting forest thinnings and timber harvest residues appears to be economically feasible at the five sites in the study that have an existing biomass power plant and other infrastructure available. The undeveloped or "greenfield" site in Greenville requires the installation of a boiler to provide steam to the ethanol process as well as buildings and other infrastructure that adds significantly to the total capital cost making this site less appealing.

### **Biomass to Ethanol Conversion Technology**

Historically, production of ethanol has been limited to using sources of soluble sugar or starch (primarily in the Midwest using corn). New technologies have been developed which now allow for the production of ethanol from "lignocellulosic biomass." Lignocellulosic biomass is the leafy or woody part of plants: wood, wood waste, paper, corn residual, sugar cane residual, etc. Lignocellulosic biomass can be processed to produce sugars that can, in turn, be fermented to ethanol.

The primary components of lignocellulosic biomass are cellulose, hemicellulose, and lignin. There are many different methods of extracting and depolymerizing the cellulose and hemicellulose to produce fermentable sugars. However, once produced, the six carbon sugars that make up the cellulose and predominate in softwood hemicellulose can be easily fermented to ethanol. The five-carbon sugars that comprise about 15% of the sugars in softwoods can also be fermented to ethanol, but the five-carbon sugars (xylose and arabinose) require mixtures of naturally occurring yeasts or genetically engineered microorganisms.

NREL has prepared design and cost estimates for three different variations of biomass to ethanol conversion technologies. The conversion technologies included in this study are:

- concentrated sulfuric acid (includes technology patented by Arkenol, Inc.)
- dilute sulfuric acid (contains no patented technology)
- dilute nitric acid (includes technology with licensing available from HFTA)

This is by no means an exhaustive list of the technology options, but is a good representation of the near-term technology options for an ethanol facility in Northeastern California. However, there are considerable differences with respect to technology maturity even among the three technologies listed above and reviewed in this report. Arkenol reports that its concentrated acid technology is ready for commercial deployment with process guaranties and efficacy insurance readily available. The stage of technology deployment can be illustrated by reviewing the list of "process concerns and recommendations" at the end of each technology section of this report. The process concerns for each of the three technologies are summarized in Table 4 below. The lack of process concerns for the concentrated acid technology indicates the more advanced state of technology development for the Arkenol process.

**Table 4. Process concerns for biomass conversion technologies. A "yes" entry indicates that additional investigation is recommended. A "no" entry indicates that the process area is not a concern with respect to technology commercialization.**

<b>Process Area</b>	<b>Concentrated Acid Process</b>	<b>Dilute Sulfuric Acid Process</b>	<b>Dilute Nitric Acid Process</b>
Hydrolysis Sugar Yields	<b>No</b>	<b>Yes</b>	<b>Yes</b>
Hydrolysis Reactor Materials of Construction	<b>No</b>	<b>Yes</b>	<b>No</b>
Hydrolyzate Fermentability	<b>No</b>	<b>Yes</b>	<b>Yes</b>
Fermentation Ethanol Yield	<b>No for yield &lt; 85% Yes for yield &gt; 85%</b>	<b>Yes</b>	<b>Yes</b>
Fermenter Yeast Propagation	<b>No</b>	<b>Yes</b>	<b>Yes</b>
Neutralizing Base	<b>No</b>	<b>Yes</b>	<b>No</b>
Facility Thermal	<b>No</b>	<b>Yes</b>	<b>Yes</b>



<b>Process Area</b>	<b>Concentrated Acid Process</b>	<b>Dilute Sulfuric Acid Process</b>	<b>Dilute Nitric Acid Process</b>
Design			
Solid/Liquid Separation Equipment	<b>No</b>	<b>Yes</b>	<b>No</b>
Lignin/Cellulose Residuals	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
Fusel Oil Production	<b>No</b>	<b>Yes</b>	<b>Yes</b>
Water Recycle	<b>No</b>	<b>Yes</b>	<b>Yes</b>
Wastewater Treatment	<b>No</b>	<b>Yes</b>	<b>Yes</b>

Note: A "yes" entry in the above table indicates additional investigation is recommended prior to technology deployment — see technology sections of the report for details.

### **Ethanol Facility Size and Capital Cost**

For this study, the size of the ethanol facility at each site is based on the amount of forest thinnings and timber harvest residue available within a 25-mile radius of the site according to the feedstock assessment report, plus any mill residue that may be available at the site. The Anderson and Martell sites were not included in the feedstock assessment so it was assumed that 265,000 bone dry tons (BDT) per year is available at these sites. This is the average biomass available at the four sites in the QLG area. If projects are to be pursued at Anderson or Martell, the feedstock availability and feedstock cost will need to be verified.

The feedstock available at each site and the resulting ethanol plant capacity (in terms of annual ethanol production) for each site and technology is shown in Table 5. The estimated facility capital cost for each technology is also shown. Capital cost is heavily influenced by the availability of existing infrastructure at each site. The capital costs were estimated by the cost estimating method known as a "factored" cost estimate which is typically used for this type of feasibility study. The accuracy of this type of cost estimate is +/-30%. At the request of NREL, Merrick Engineers and Architects of Denver, Colorado, performed a technical review of NREL's dilute sulfuric acid process design as well as the capital and operating cost estimates for the Greenville site. Merrick's comments and suggestions were incorporated into all three technology designs and cost estimates where appropriate. Merrick's report is included in Volume II of the *Biomass to Ethanol Facility Design, Cost Estimate, and Financial Evaluation* report.

In the far right column of Table 5, the "installed cost per gallon ethanol" is shown. This is a common

measure of the capital cost versus the ethanol production capacity of an ethanol facility and ranges from \$2.50 to \$5.43 for this study. A fairly large corn ethanol dry mill facility (40 million gallons per year) can be built for \$1.00 to \$2.00 per gallon ethanol capacity. The installed cost for the dilute nitric acid biomass to ethanol technology drops to about \$1.75 per gallon ethanol when the size of the facility is increased to 40 million gallons per year. This compares favorably to the corn ethanol industry capital cost.

**Table 5. Feedstock Available, Ethanol Plant Size, and Facility Capital Cost (1997 dollars)**

<b>Site Technology</b>	<b>Feedstock Feedrate (BDT/year)</b>	<b>Plant Size <sup>1</sup> (million gallon ethanol/year)</b>	<b>Facility Capital Cost <sup>2</sup> (million \$)</b>	<b>Installed Cost per Gallon Ethanol</b>
<b>Anderson</b>	265,000			
Concentrated acid		22.3	\$90.2	\$4.04
Dilute sulfuric		13.8	\$46.7	\$3.39
Dilute nitric		13.8	\$34.4	\$2.49
<b>Chester</b>	298,000			
Concentrated acid	(includes 30,000	25.1	\$99.5	\$3.97
Dilute sulfuric	BDT of mill	15.5	\$55.1	\$3.55
Dilute nitric	residue)	15.5	\$40.4	\$2.61
<b>Greenville</b>	335,000			
Concentrated acid		28.2	\$114.4	\$4.06
Dilute sulfuric		17.4	\$69.2	\$3.98
Dilute nitric		17.4	\$52.2	\$3.00
<b>Loyalton</b>	228,000			
Concentrated acid	(includes 41,000	19.1	\$87.7	\$4.59
Dilute sulfuric	BDT of mill	11.8	\$48.0	\$4.07
Dilute nitric	residue)	11.8	\$34.8	\$2.95
<b>Martell</b>	265,000			
Concentrated acid		22.3	\$94.1	\$4.22
Dilute sulfuric		13.8	\$51.9	\$3.76
Dilute nitric		13.8	\$37.8	\$2.74
<b>Westwood</b>	271,000			
Concentrated acid		22.8	\$95.1	\$4.17
Dilute sulfuric		14.1	\$52.5	\$3.72
Dilute nitric		14.1	\$38.2	\$2.71

<sup>1</sup> Plant size for various technologies based on respective yields from the same feedstock feedrate.

<sup>2</sup> Facility Capital Cost includes total fixed capital investment and working capital. The accuracy of the capital cost estimate is +/- 30%.

### ***Financial Evaluation***

Internal rate of return (IRR) was calculated for each technology and each site resulting in 18 combinations of technologies and sites. Assumptions made to conduct the financial analysis include 20-year project life, 100% owner equity financing, 95% on-line factor (345 operating days per year), ethanol selling price of \$1.20 per gallon, and a feedstock cost of \$20 per bone dry ton (BDT).

Additionally, all scenarios for sites with a biomass boiler assume that the lignin/cellulose residue from fermentation is sold to the host site owner for biomass boiler fuel. The selling price for the lignin/cellulose residue is assumed to be \$25 per BDT (slightly higher than the base feedstock cost due to the higher energy content of the residue). For the Greenville site, the selling price of the residue has been reduced to \$15 per BDT to cover the cost of transportation to a nearby biomass power facility.

Credit for carbon dioxide (CO<sub>2</sub>) sales is not included in any of the scenarios except for those for the Anderson site. Up to two tons per hour of CO<sub>2</sub> could potentially be sold to Simpson Paper and Pfizer Specialty Chemicals at the Anderson site (R. Bell, Simpson Paper Company). A selling price of \$10 per ton for two tons per hour of unprocessed CO<sub>2</sub> (not purified or liquified) has been assumed for the Anderson site.

Additional key economic assumptions are shown in Table 6 below.

**Table 6. Key Economic Assumptions**

<b>Parameter</b>	<b>Assumed value</b>
Plant life	20 years
Reference year	1997
Design, construction and startup period	2 years
Owner equity	100%
Feedstock cost, delivered	\$20.00 per BDT
Ethanol selling price	\$1.20 per gallon
Operating days per year	345

<b>Parameter</b>	<b>Assumed value</b>
Inflation rate	3%
Federal income tax rate	34%
California income tax rate	6%

Results of the economic analysis reported as internal rate of return (IRR) for each site and each technology are shown in Table 7. The IRR for the concentrated acid and the dilute nitric acid technologies are nearly the same, and both are significantly higher than the dilute sulfuric acid technology.

**Table 7. Internal Rate of Return (IRR) for 100% Owner Equity**

<b>Site</b>	<b>Concentrated Acid</b>	<b>Dilute Sulfuric Acid</b>	<b>Dilute Nitric Acid</b>
Anderson	5%	5%	11%
Chester	7%	5%	11%
Greenville	4%	-3%	3%
Loyalton	5%	2%	9%
Martell	6%	4%	10%
Westwood	6%	4%	10%

## **Project Financing**

Projects of this magnitude are rarely financed with 100% owner equity. It is well known that favorable financing terms can be used to leverage the owner's equity and dramatically improve the IRR. A scenario with 25% owner equity and 75% debt financing was evaluated. A loan interest rate of 7% and a 10 year loan term was chosen to represent perhaps the best possible financing scenario. A 7% interest rate loan may be available through the new electric utility restructuring Public Interest Energy Research (PIER) Program (to be administered by the California Energy Commission), through the California Pollution Control Financing Authority, or the California Alternative Energy Financing Authority.

Results of the IRR calculations with 25% owner equity and 75% debt financing at 7% interest rate are shown in Table 8. Leveraging effects are not significant unless the IRR at 100% owner equity is higher than the net loan interest rate (the "after tax" interest rate). These results demonstrate that strong IRRs are possible. However, these projects are capital intensive and with relatively high risk and may, therefore be difficult to finance.

**Table 8. Internal Rate of Return (IRR) for 25% Owner Equity**

Site	Concentrated Acid	Dilute Sulfuric Acid	Dilute Nitric Acid
Anderson	8%	9%	25%
Chester	15%	9%	25%
Greenville	7%	-4%	6%
Loyalton	9%	4%	18%
Martell	12%	7%	22%
Westwood	12%	7%	23%

### Cash Cost of Production and Net Production Cost

The full cash cost of production and net ethanol production cost with 25% owner equity was determined. Full cash cost and net production cost are defined as follows:

$$\begin{aligned}
 & \text{variable costs} && \text{(raw materials and utilities)} \\
 + & \text{fixed costs} && \text{(labor and labor related costs, plant overhead,} \\
 & && \text{maintenance, supplies, local taxes and insurance)} \\
 - & \text{coproduct credits} && \text{(for lignin, CO}_2\text{, and cell mass)} \\
 = & \text{full cash cost of production} \\
 + & \text{capital depreciation} \\
 + & \text{financing costs} && \text{(net interest on debt financing)} \\
 = & \text{net ethanol production cost}
 \end{aligned}$$

The resulting full cash cost of production and net production costs for each technology and each site are shown in the Table 9 below.

**Table 9. Full Cash Cost / Net Ethanol Production Cost, \$/ gal. ethanol, 25% owner equity**

Site	Concentrated Acid		Dilute Sulfuric Acid		Dilute Nitric Acid	
	Cash	Net	Cash	Net	Cash	Net
Anderson	\$0.74	\$1.03	\$0.83	\$1.06	\$0.71	\$0.89
Chester	\$0.62	\$0.90	\$0.80	\$1.05	\$0.68	\$0.86
Greenville	\$0.76	\$1.05	\$1.04	\$1.31	\$0.93	\$1.13
Loyalton	\$0.67	\$1.00	\$0.87	\$1.15	\$0.74	\$0.94
Martell	\$0.64	\$0.94	\$0.83	\$1.09	\$0.70	\$0.89
Westwood	\$0.64	\$0.94	\$0.82	\$1.08	\$0.70	\$0.89

### Maximum Feedstock Cost

One of the objectives of the Quincy Library Group is to facilitate thinning the forests in the area to reduce wildfire threat and improve forest health. One of the major obstacles to thinning large numbers of acres each year is the cost. Ethanol production utilizing the forest thinnings as feedstock may be a way to offset all or a significant portion of the thinning costs. A scenario was evaluated to determine the maximum feedstock cost that an ethanol facility could pay and still return 15% IRR on the owner's equity for the ethanol facility. The 15% IRR in this type of analysis is also known as the "hurdle rate." Again, owner equity was assumed to be 25% with 7% interest on the remaining debt. The results are shown in Table 10 for each site and technology.

**Table 10. Maximum Feedstock Cost, 15% Hurdle Rate and 25% Owner Equity**

Site	Concentrated Acid	Dilute Sulfuric Acid	Dilute Nitric Acid
Anderson	\$7.79	\$14.23	\$26.73
Chester	\$19.17	\$14.55	\$27.58
Greenville	\$6.50	-\$0.58	\$12.36
Loyalton	\$7.56	\$7.64	\$22.40
Martell	\$14.34	\$11.67	\$25.44
Westwood	\$15.33	\$12.21	\$25.87

### *Sensitivity Analyses*

The sensitivity of project profitability (as measured by IRR) to the following critical variables was also evaluated:

- Ethanol plant size
- Delivered feedstock cost
- Feedstock composition (% glucan)
- Ethanol selling price
- Owner equity
- Ethanol facility capital cost
- Annual manufacturing cost
- Annual direct labor cost

Sensitivity analyses were performed for the dilute nitric acid process at the Chester site only because this site and process has a high IRR and the sensitivity analyses are very time intensive. Again, owner equity was assumed to be 25% with 7% interest on the remaining debt. The results are summarized in Table 11 below. Graphs of the IRR versus the above sensitivity variables are included in the *Biomass to Ethanol Facility Design, Cost Estimate, and Financial Evaluation* report.

The IRR is most sensitive to feedstock cost and owner equity. Ethanol plant size, annual manufacturing cost, ethanol selling price, ethanol facility capital cost, and feedstock composition all display moderate sensitivities. A 30% change in direct labor cost has relatively little effect on the IRR. A graph of the IRR versus feedstock cost for the dilute nitric acid technology at the Chester site follows (Figure 2).

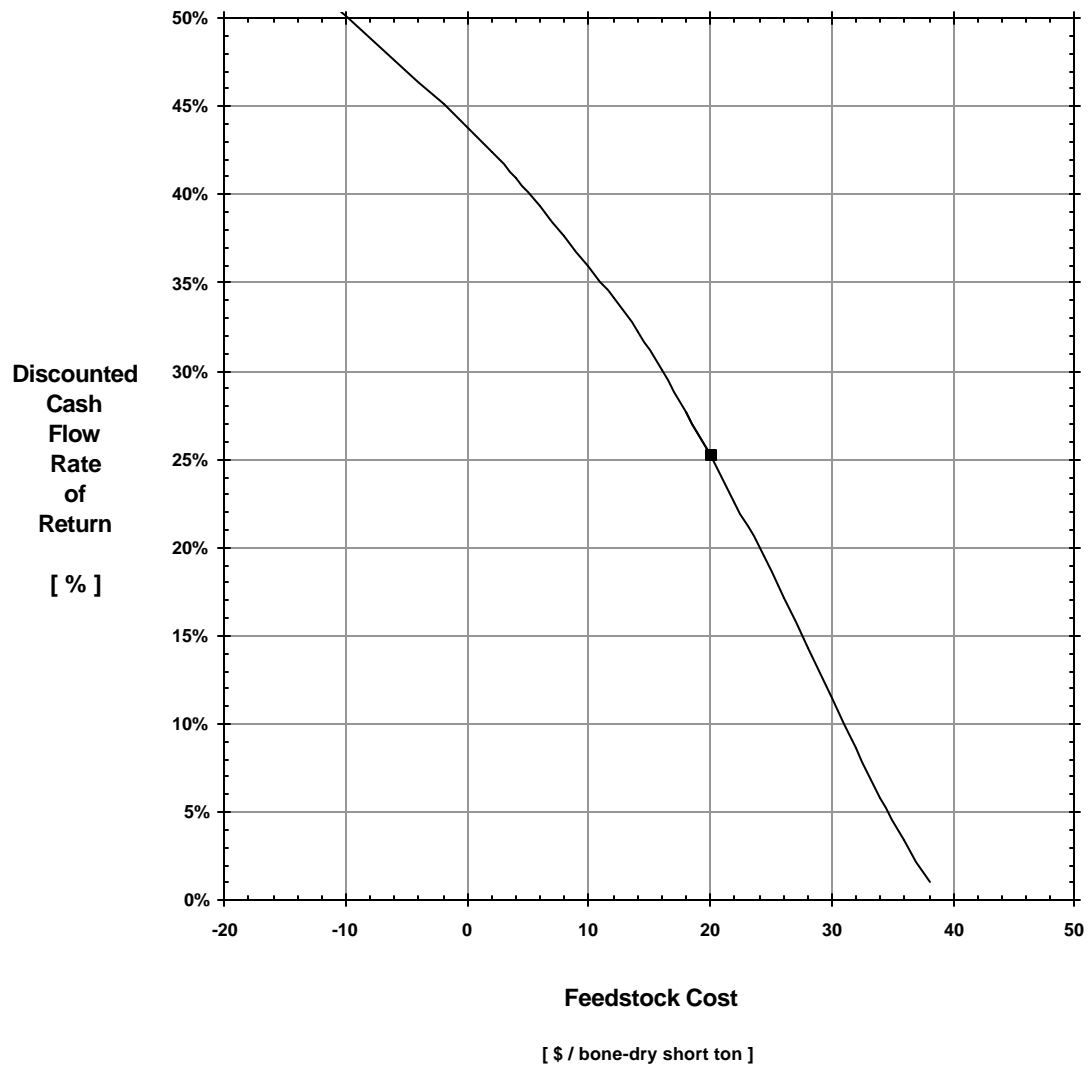
**Table 11. Summary of sensitivities for Chester site and dilute nitric acid process.**

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<b>Sensitivity Variable and Rank - High to Low</b>	<b>Sensitivity Range</b>	<b>Corresponding IRR Range (Ä%)</b>
1. Delivered feedstock cost	\$38 - \$0 per BDT feedstock	1% to 44% (43%)
2. Owner equity	100% to 5% equity	11% to 50% (39%)
3. Ethanol plant size	6 - 19 million gal. ethanol/year	0% to 31% (31%)
4. Annual manufacturing cost	+/- 20% of manufacturing cost	9% to 38% (29%)
5. Ethanol selling price	\$1.00 - \$1.40 per gal. ethanol	11% to 36% (25%)
6. Ethanol facility capital cost	+/- 30% of capital cost	17% to 37% (20%)
7. Feedstock composition	33 - 53% glucan in feedstock	14% to 34% (20%)
8. Annual direct labor cost	+/- 30% of direct labor cost	23% to 28% (5%)



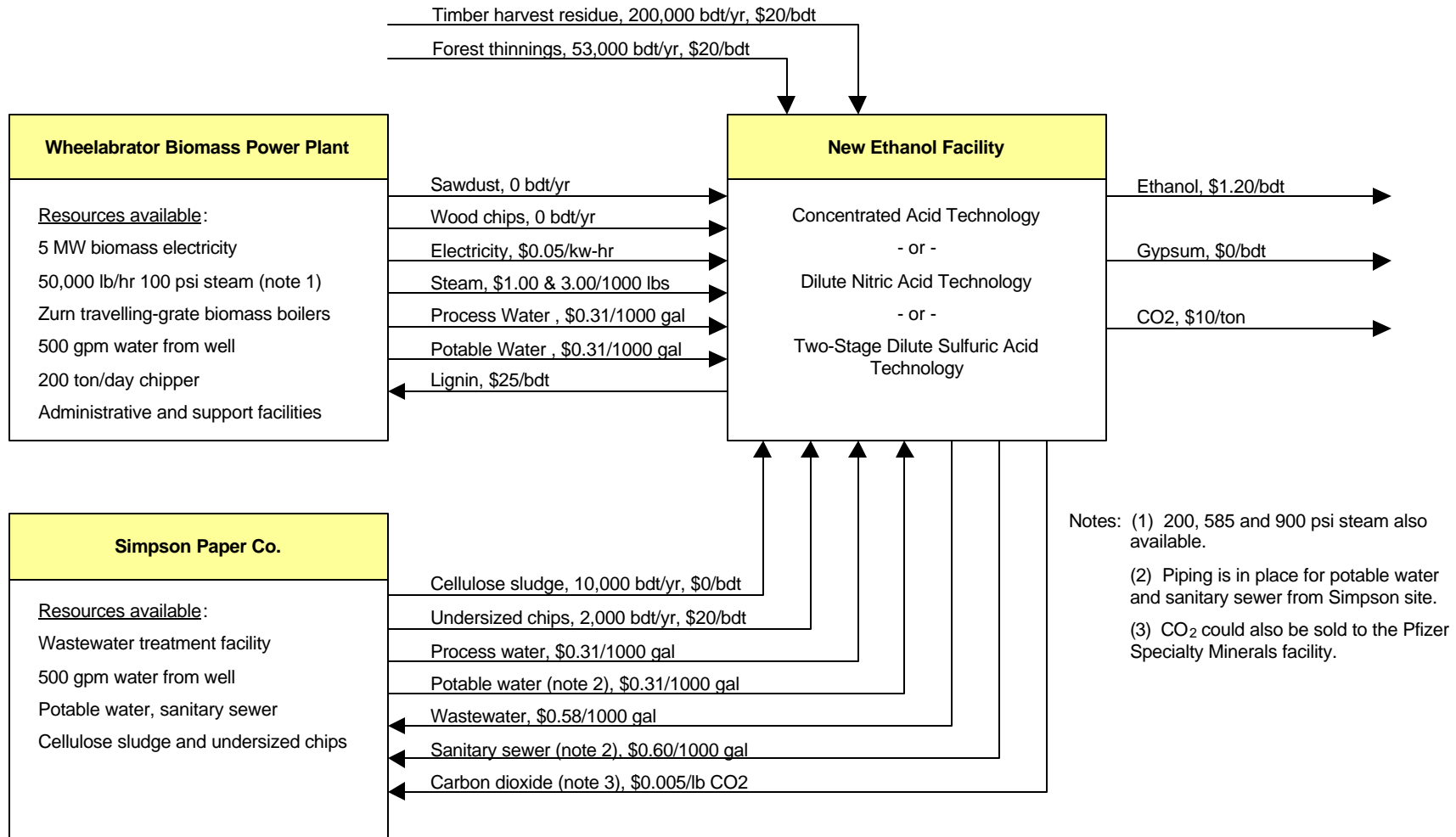
## Discounted Cash Flow Rate of Return vs Feedstock Cost



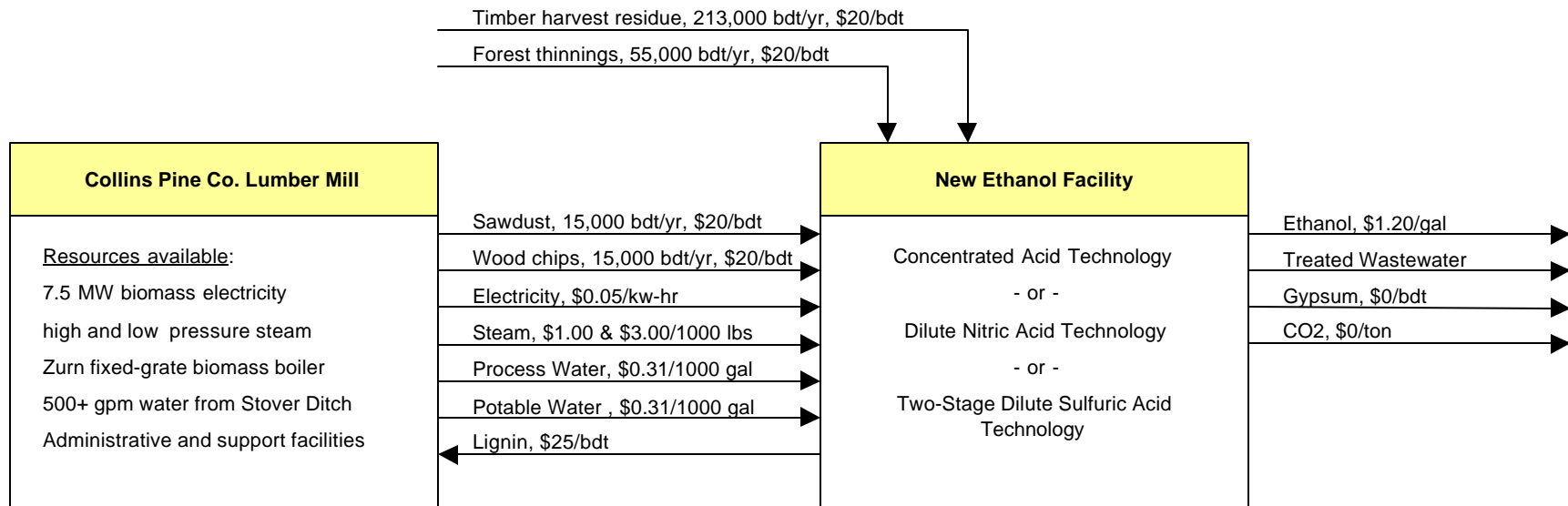


# Anderson, California Site

## Roseburg Forest Products

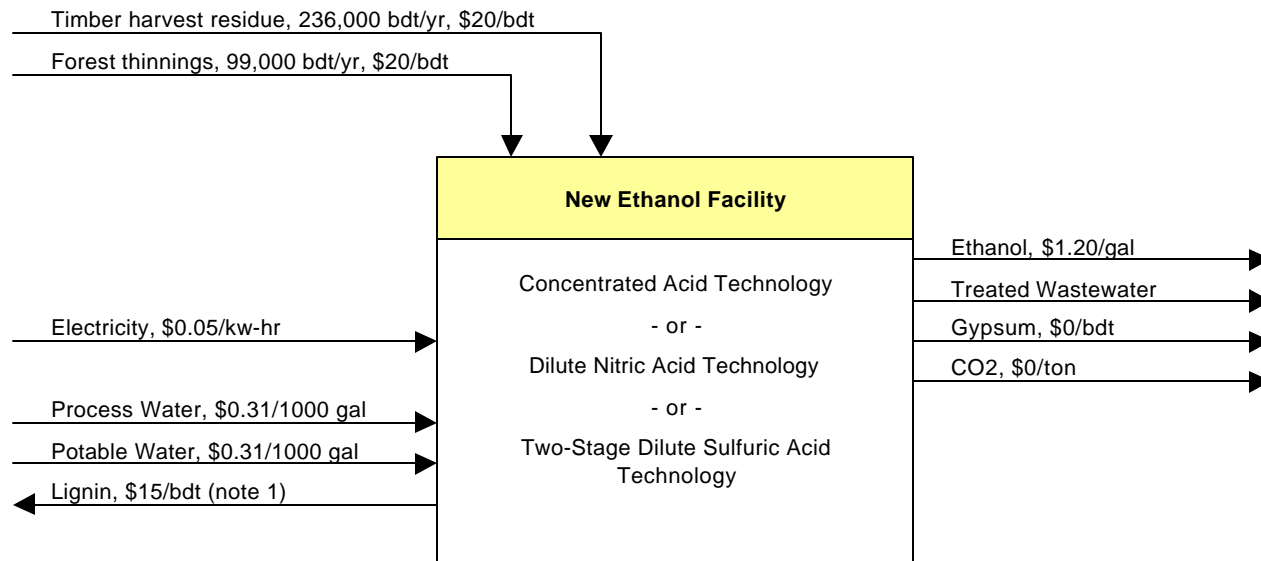


## Chester, California Site Collins Pine Co.



# Greenville, California Site

## Carl Pew Property

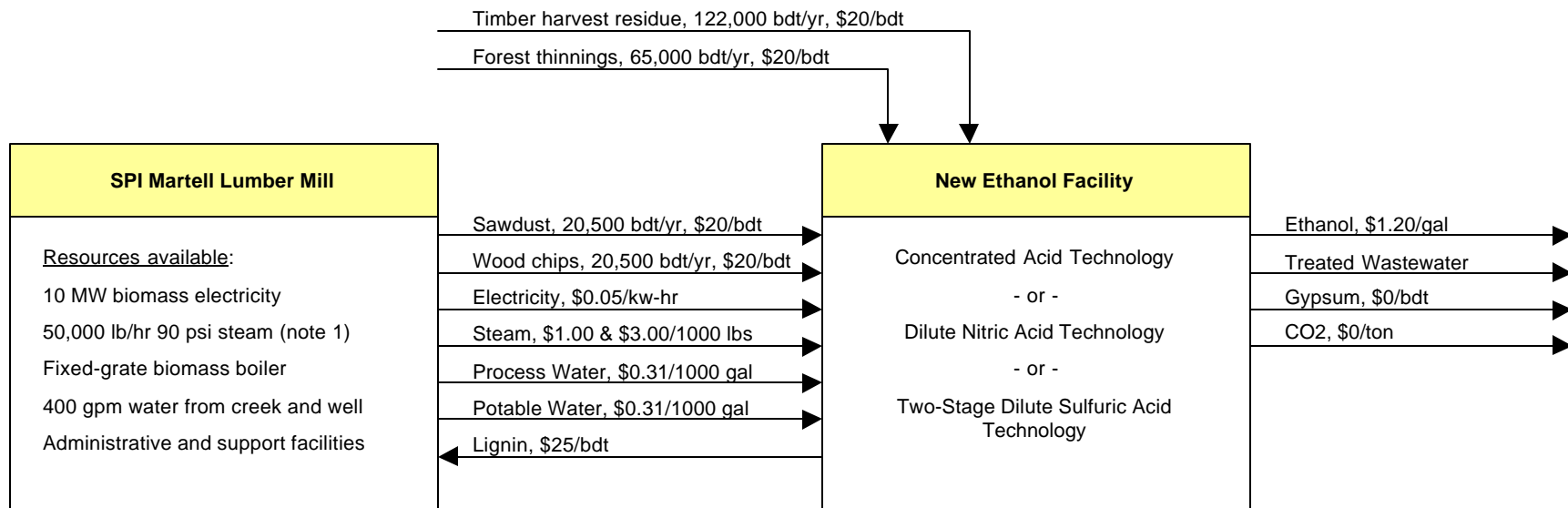


Notes: (1) Lignin to be sold to a nearby biomass power plant.



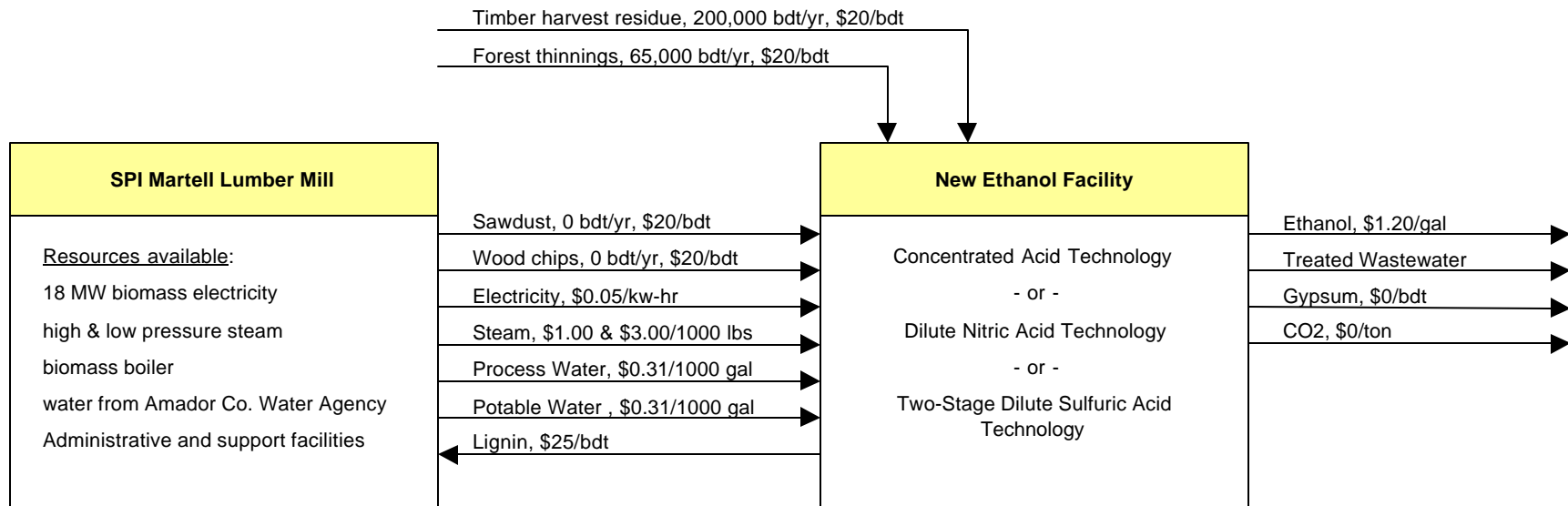
# Loyalton, California Site

## Sierra Pacific Industries



Notes: (1) 865 psi steam is available from the boiler -- this pressure and temperature can be reduced with a steam attemperator.

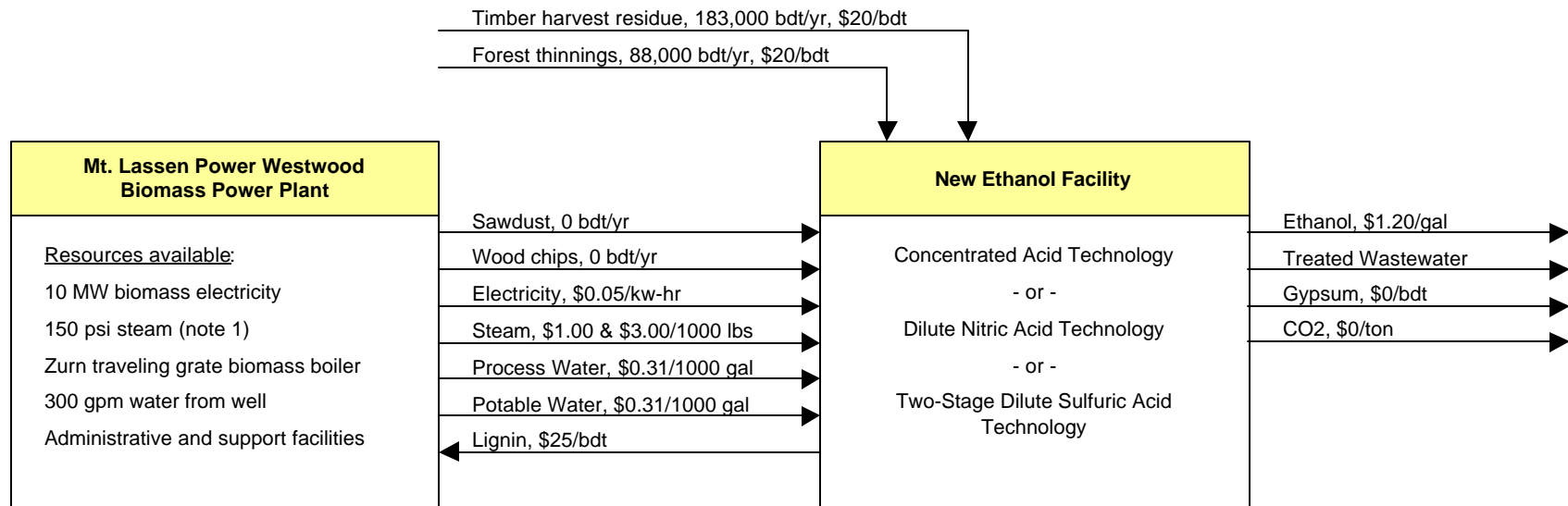
## Martell, California Site Sierra Pacific Industries





# Westwood, California Site

## Mt. Lassen Power



Notes: (1) Each 10,000 pound per hour (pph) of steam used, decreases net electricity output by 1 MW. e.g. at 40,000 pph steam use, net electricity output is 6 MW.  
Superheat can also be added to the steam.



## ***Environmental Issues***

### **Off-Site Environmental Impacts**

The potential environmental effects of operating a commercial-scale biomass-to-ethanol plant include both the on-site and off-site impacts surrounding the production facility.

The on-site environmental impacts (as well as local community impacts) are discussed in the site-specific evaluations conducted by the California Energy Commission in the *Site Characterization Study* issued in April 1997. The CEC study reviewed various environmental and infrastructure factors at the six study sites in Northeastern California.

Cellulose biomass material will be generated from both public and private forest lands within at least a 25-mile radius of the ethanol facility. TSS Consultants' *Feedstock Supply and Delivery Systems* report (June 1997) predicts an available and sustainable, annual supply of between 187,000 and 336,000 Bone Dry Tons (BDT), dependent upon site. Sources of biomass will be timber harvesting by-products, certain lumber mill residues as well as forest fuels reduction treatments. The same report, using the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection, defined that USFS holdings (within 25 miles of the four QLG sites) ranged between 53% to 64%. This includes all lands, not just forested lands. Federally managed forest lands are expected to be a higher percentage.

Environmental reviews and public participation processes that are prerequisites for authorizing biomass harvest differ between land ownership types. On private timberlands, California Forest Practice Rules govern timber harvest practices. Biomass harvest activities on National Forest System lands - the presumed primary source for any ethanol facility within the Quincy Library Group's area of interest since the majority of the forest lands are federally administered - must be subjected to National Environmental Policy Act (NEPA) reviews and public participation processes of the U.S. Forest Service. Projects on federal lands must also have the environmental review conducted within the current regional or national context, which must take into account the "latest science."

The Sierra Nevada Ecosystem Project Report (Davis: University of California, Centers for Water and Wildland Resources, 1996)—referred to as SNEP— was a multi year Congressionally mandated, interdisciplinary, scientific review of the status of the Sierran ecosystem. It is the most recent science on a broad scale. The SNEP Summary notes that:

- Live and dead fuels in today's conifer forests are more abundant and continuous than in the past. (P.26).
- Timber harvest, through its effect upon forest structure, local microclimate, and fuel accumulation, has increased fire severity more than any recent human activity. If not accompanied by adequate

reduction of fuels, logging (including salvage of dead and dying trees) increases fire hazard by increasing surface dead fuels and changing the local microclimate. Fire intensity and expected fire spread rates thus increase locally and in areas adjacent to harvest. However, logging can serve as a tool to help reduce fire hazard when slash is adequately treated and treatments are maintained. (P.26).

- Human activities, particularly timber harvest...and fire suppression, have drastically reduced the extent of late successional forests through the removal of large trees...(P.6).
- The aquatic/riparian systems are the most altered and impaired habitats in the Sierra. (P.8).

The plan proposed by the QLG intentionally reduces the environmental impacts of the large scale-thinning program that is proposed (> 50,000 acres per year for five years) through adoption of various measures on US Forest Service lands designed to reduce those impacts. These measures include:

- Use of the Scientific Assessment Team (SAT) riparian standards for timber harvest activities, which typically preclude timber harvest within two "site tree" lengths of a perennial stream;
- Precluding timber harvests on the primary old growth and anadromous fish stream areas of the forest by defining those areas as "Off-Base" or "Deferred" from timber harvests;
- Adoption of the California Spotted Owl guidelines (1993), which preclude trees over 30 " from harvesting as well as limit basal area and tree canopy reductions from thinning programs; and
- Precluding timber harvests in so-called "Spotted Owl Protected Activity Centers" (PACs) and "Spotted Owl Habitat Areas" (SOHAs).

The typical kinds of environmental concerns that arise from timber harvest and biomass harvest activities include the effects of roads and landings, riparian zone and water quality impacts, fuel loadings and arrangements, wildlife disturbances, and changes in suitability of wildlife habitats. Generically, these can be grouped into soil, water and wildlife impacts. The Plumas, Lassen, and Tahoe National Forest Plans have standards and guidelines applicable to the protection of soil, water, and wildlife resources and the USFS region has adopted a series of BMPs.

The two Quincy Library Group bills currently in the US Congress (HR 858 was approved by the US House of Representatives on 7/10/97 and S 1028 was introduced on 7/17/97) both call for an Environmental Impact Statement on the forestry portion of the QLG plan. This EIS would be developed and finalized within 200 days from enactment of the QLG bill. This EIS would allow all specific projects to be "tiered" to the QLG EIS, thus allowing for a simpler environmental analysis for individual projects (e.g. archaeology, seasonal botany, on-site nesting areas, etc.) that focuses on the site-specific issues present in any land disturbing process. Monitoring would take place and the larger temporal and landscape scales.

## Project Environmental Permits

The CEC Energy Facilities Siting and Environmental Protection staff provided information on the types and time required to obtain the environmental permits required for a project such as the biomass to ethanol facility proposed here. The air quality, biology, transmission system evaluation, and water quality permits listed in Table 12 will be required. The CEC estimates that each of these permits will require about six months to obtain. There may be additional permits required from local communities where the project may be located. The CEC can identify these additional permits once more specific project details are known.

**Table 12. Environmental permits required for a biomass to ethanol facility.**

Technical Area	Regulatory Agency	Permit/Application	Time Period <sup>1</sup>
Air Quality	Local Air Quality Management District	Application	
		Letter of Completeness	30 days
		Authority to Construct	180 days
		Permit to Operate	
Biology <sup>2</sup>	California Department of Fish and Game	1. Streambed Alteration Agreement 2. Endangered Species Take	6 months
	United States Fish and Wildlife Service	Endangered Species Take	6 months
	Army Corp of Engineers	Headwaters and Isolated Waters Discharge	6 months
Transmission System Evaluation	Pacific Gas & Electric	Special Facilities Agreement <sup>3</sup>	120 days
		Interconnection Facilities Agreement <sup>4</sup>	120 days
Water	Regional Water Quality Control Board (RWQCB)	National Pollutant Discharge Elimination System Permit - NPDES (wastewater discharged to surface water)	6 months
		Waste Discharge Requirement - WDR (discharges to land)	6 months
		WDR (underground injection)	6 months

<sup>1</sup> All time periods listed are approximations

<sup>2</sup> Permits associated with biology can be obtained simultaneously

<sup>3</sup> Biomass-to-ethanol projects may need the special or interconnection facility agreement with PG&E.

<sup>4</sup> Ibid.

With the threat of global warming and energy crises in today's environment, the need for clean, "green" fuels is quickly becoming a necessity. Ethanol is an environmentally friendly fuel that is used in 10% blends without engine modifications or in 85% blends in specially designed engines. A blend of 10% ethanol with gas is an approved motor fuel outside of California and is included in all engine warranties that require unleaded gasoline. Motorboats, snowmobiles, motorcycles, lawn-mowers, chainsaws etc. can all utilize the cleaner gasoline/ethanol fuel blend. Most importantly, millions of automobiles on the road today use this improved fuel.

Ethanol is a liquid alcohol that is manufactured by the fermentation of grains such as wheat, barley, corn, wood, and sugar cane (in Brazil). Although it has been traditionally thought of as a beverage product for use in spirits, beer and wine, ethanol is an important, viable alternative to unleaded gasoline fuel. It is a high-octane fuel with high oxygen content (35% oxygen by weight) and when blended properly in gasoline produces a cleaner, and more complete combustion.

The use of ethanol in gasoline has several environmental benefits:

- CO, hydrocarbon and NOx reductions: the use of ethanol causes reductions of 8% to 24% in emissions of carbon monoxide (CO) with a 10% ethanol blend. Hydrocarbon emissions are also reduced with ethanol fuel blends. Emissions of nitrogen oxides (NOx) may be slightly reduced or slightly increased in some cases.<sup>5</sup>
- CO<sub>2</sub> reduction: although carbon dioxide is released when ethanol burns, it is recycled into organic tissue during plant growth; ethanol use in gasoline can result in a net reduction in atmospheric carbon dioxide levels.
- Renewable resource: ethanol is derived from renewable biological feedstocks such as agricultural crops and forestry by-products.

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<sup>5</sup> Office of Science and Technology Policy, Executive Office of the President, *Air Quality Benefits of the Winter Oxyfuel Program*, March 1996.

## ***Market Issues***

### **Ethanol Market Issues**

This section on Ethanol Market Issues contains information provided by the California Institute of Food and Agricultural Research at the University of California, Davis; Parallel Products of Davis, CA; and SWAN Biomass Company of Dowers Grove, IL.

To improve the security of liquid fuel supplies, while creating jobs and businesses in rural areas, the federal government has provided a tax incentive to promote the use of ethanol in gasoline. In addition, many states also provide an ethanol production tax incentive or a tax incentive to build ethanol plants. As a result of the federal and state incentives, annual fuel ethanol production by fermentation of glucose from corn has increased to approximately 1.5 billion gallons in the United States; current annual domestic ethanol sales are over \$1 billion and are expected to increase. Roughly 10% of the total U.S. gasoline supply is now E10 or "gasohol," a blend of 10% ethanol with 90% gasoline. Initially, the value of E10 was seen primarily as a gasoline extender to reduce dependence on imported petroleum while stimulating the U.S. economy, especially in the underdeveloped rural areas. With current regulations on the composition of gasoline in areas where air pollution has been a problem, fuel ethanol has taken on its most valuable role as an oxygenated gasoline additive. Additionally, the use of ethanol as an antiknock additive to replace lead formerly added to premium gasoline has also been recognized.

In California regulatory policies of the California Air Resources Board (CARB) have essentially precluded ethanol from the oxygenate market for California reformulated gasoline (CA RFG). California state law provides for a vapor pressure allowance for ethanol when blended with gasoline at a level of 10% by volume (this produces 3.5% oxygen in the gasoline). However, CARB policy limits the amount of oxygen in CA RFG to a maximum of 2% oxygen, thus preventing the utilization of the vapor pressure allowance for ethanol. Refiners are unwilling and in some cases incapable of producing a base gasoline that can be combined with ethanol at 2% oxygen and meet the vapor pressure requirement of CA RFG without the vapor pressure allowance. Blending ethanol at less than 10% by volume also reduces the value of the federal tax incentive, which effectively increases the cost of the ethanol.

Consequently, ethanol (which historically has enjoyed a significant market presence in California) has not been used in California gasoline since CA RFG was introduced in 1996. This has created a virtual monopoly for MTBE in California. Removing the regulatory barriers to the use of ethanol in CA RFG will create greater flexibility for refiners and gasoline blenders in meeting CARB regulations. This would encourage the use of renewable fuels and the development of a large ethanol production industry in California. The potential size of this new industry is discussed below.

Ethanol demand in the western states of California, Arizona, Nevada, Oregon and Washington increased from 154 million to 214 million gallons per year from 1992 to 1995. In 1996, ethanol demand dropped to 124 million gallons per year with the loss of the California market and a significant decrease in the

Washington market. Ethanol demand is driven primarily by federal and state Clean Air Act requirements mandating the use of oxygenates in winter gasoline to lower carbon monoxide emissions. The annual gasoline demand, required oxygenate level in the state's RFG or winter gasoline, and the estimated winter oxygenate season ethanol sales for 1992 through 1997 are shown in Table 13 below.

**Table 13. Historical West Coast Ethanol Demand (1992 through 1997).**

<b>State</b>	<b>Annual Gasoline Demand (1000 gal)</b>	<b>Oxy Level (% by wt.)</b>	<b>Ethanol Est. sales 92-93 (1000 gal)</b>	<b>Ethanol Est. sales 93-94 (1000 gal)</b>	<b>Ethanol Est. sales 94-95 (1000 gal)</b>	<b>Ethanol Est. sales 95-96 (1000 gal)</b>	<b>Ethanol Est. sales 96-97 (1000 gal)</b>
CA	13,000,000	2.0	50,000	50,000	50,000	50,000	0
AZ	1,800,000	2.7	9,300	15,500	46,500	62,000	62,000
NV	750,000	3.5	4,900	9,750	18,000	26,750	29,000
WA	2,400,000	2.7	60,000	60,000	50,000	50,000	7,500
OR	1,500,000	2.7	30,000	25,000	25,000	25,000	25,000
<b>Totals</b>	<b>19,450,000</b>		<b>154,200</b>	<b>160,250</b>	<b>189,500</b>	<b>213,750</b>	<b>123,500</b>

Current ethanol production capacity on the west coast is only 14 million gallons per year— approximately 6 million gallons per year is produced in California and 8 million gallons per year in Washington. The remainder is imported from the midwest. Production of ethanol in California would result in significantly lower transportation costs to the west coast ethanol markets providing an advantage for projects such as a biomass to ethanol project in the QLG area. California ethanol producers could have up to a \$0.20 per gallon cost advantage over midwest producers due to transportation costs.

Ethanol pricing is impacted by variables such as corn prices, MTBE prices, gasoline prices, and clean air act regulations. In the last five years, wholesale delivered prices to western ethanol markets have ranged between \$1.18 and \$1.55 per gallon (Table 14). Given the seasonal nature of the demand, winter prices tend to be significantly higher than summer prices. 1996 was an exceptional year due to historically high corn prices resulting in high ethanol prices throughout the year. In 1997, ethanol prices have returned to traditional levels of \$1.25 to \$1.30 per gallon. The expansion of ethanol production based on forest thinnings and agricultural wastes would promote the RFG and oxygenated fuel programs in the western U.S. and would lead to more stable ethanol pricing.



The current market for California ethanol is outside of California due to the policy issues discussed above. The current west coast market is approximately 125 million gallons of ethanol per year. California ethanol should enjoy a cost advantage due to significantly lower transportation costs compared to ethanol produced in the Midwest. The west coast ethanol market is projected to parallel the growth of the U.S. ethanol market at 3% per year.

**Table 14. Average Wholesale Ethanol Prices Delivered to West Coast Markets**

<b>Year</b>	<b>Mandate Season Average Price per Gallon</b>	<b>Non-Mandate Season Average Price per Gallon</b>	<b>Average Annual Price per Gallon</b>
1992	\$1.55	\$1.25	\$1.38
1993	\$1.35	\$1.20	\$1.26
1994	\$1.40	\$1.24	\$1.30
1995	\$1.25	\$1.18	\$1.21
1996	\$1.50	\$1.50	\$1.50
<b>Average</b>	<b>\$1.41</b>	<b>\$1.27</b>	<b>\$1.33</b>

The west coast ethanol market could expand dramatically if the California RFG market becomes available to ethanol. California legislation or policy changes could create a market potential of 750 million gallons per year for ethanol produced in California and utilized as E10 in existing vehicles. The wide spread use of flexible fuel vehicles and alternative fuel buses utilizing E85 (85% ethanol blended with 15% gasoline) could increase this amount. Feedstock availability limitations and resultant feedstock cost growth could impact the economics and reduce the rate of market penetration. Energy crops could become economic and contribute to additional growth.

In addition to E10 and E85, ethanol can be used as a feedstock for production of ethyl tertiary butyl ether (ETBE). ETBE is a premium ether that can be used instead of ethanol or MTBE to oxygenate gasoline. The use of MTBE is being challenged in California and elsewhere because of ground water contamination and other potential environmental and health impacts stemming from its use. Thus, expanded use of MTBE or ETBE may not be popular with policy makers or the public. However, ETBE has characteristics that might make it less harmful to the environment, so its use may be endorsed as a "bridge" to allow time for the installation of greater capacity to manufacture renewable fuels like ethanol.

### **Carbon Dioxide Market Issues**

Carbon dioxide is normally recovered for industrial purposes from combustion flue gases or as a by-product of ammonia or hydrogen production. Large quantities of CO<sub>2</sub> are also produced as a byproduct of ethanol fermentation. CO<sub>2</sub> is unusual in that it only exists as a liquid under pressure and normally sublimates as a gas straight from its solid form. Like a number of other gases, carbon dioxide's inert qualities make it useful for preventing or suppressing combustion or oxidation. Its major use, however, is as a refrigerant or cooling agent. Solid carbon dioxide at -80°C is used for chilling and freezing in the food industry.

Carbon dioxide gas dissolves easily in water, making the resultant solution slightly acidic. As a result, it is often used to balance the pH of water in preference to the addition of mineral acids. Its solubility also makes it the preferred method for putting the "fizz" into drinks of all kinds.

Applications of carbon dioxide include:

- Food freezing, chilling and refrigeration
- Fire suppression
- Alkali neutralization, waste treatment
- Mould setting
- Inert gas pressurization
- Beverage carbonation
- Tobacco expansion
- Oil well recovery
- Plant growth
- Carrier gas for deodorants, odorants, pesticides and the like
- Breathing stimulant

It appears that the existing CO<sub>2</sub> production capacity far exceeds the demand in northern California. Most of the CO<sub>2</sub> market for this area is in the beverage market for carbonization and for poultry freezing. A beverage facility could use as much as 40,000 to 50,000 tons per year. R. Bell of Simpson Paper in Anderson, California reports that Simpson and Pfizer Speciality Chemicals may be able to utilize 15,000 to 20,000 tons of CO<sub>2</sub> per year produced at a biomass ethanol facility at the Anderson site. The ethanol plants under consideration for the QLG area would produce 13,000 to 35,000 tons of CO<sub>2</sub> per year.

The market price for carbon dioxide is approximately \$75/ton, FOB the customer, nationwide. Small markets for welding supplies could be as high as \$150 to \$160/ton. The estimated capital required to build a facility to liquefy CO<sub>2</sub> production of approximately 100 tons per day is approximately \$2.5 to \$3 million plus an additional \$200,000 to \$500,000 to clean up the CO<sub>2</sub>. The cleanup is dependent upon the amount of sulfur and hydrocarbons in the gas. Fermentation CO<sub>2</sub> contains no sulfur and very little hydrocarbons.

Because of the oversupply of CO<sub>2</sub> in northern California, no credit for CO<sub>2</sub> sales is assumed in the economic analyses except for the Anderson site where two existing users are already in place. It may be

possible to develop CO<sub>2</sub> markets in Sacramento and Reno for the fermentation CO<sub>2</sub> produced by the proposed ethanol facilities, but this is beyond the scope of the current feasibility study.

### ***Socioeconomic Impacts***

The socioeconomic report reviews the local, regional and statewide implications of building and operating a forest biomass to ethanol manufacturing facility at specified sites in the Quincy Library Group area (Lassen, Plumas and Sierra counties in the Sierra Nevada) or other sites in Northern California. The report first sets the current socioeconomic context in this natural resource dependent area. It then reviews the effect of an ethanol plant on employment, personal incomes, state and local taxes, construction jobs, and local infrastructure (particularly roads, schools and utilities). It also reviews the implications of such a facility in Amador or Shasta County.

A modest sized forest biomass to ethanol demonstration plant (e.g. producing 15 million gallons per year) will create at least 28 direct jobs at the plant, if it is co-located with an existing biomass electricity energy plant. Additional jobs would be created if a biomass electric energy plant was built along with the ethanol manufacturing facility. The furnishing of forest biomass feedstock to this plant would employ 63-100 additional employees to gather, process and transport the cellulose material to the plant. These 91-128 direct jobs would be augmented by an additional 93-122 indirect or multiplier jobs. One 15 million gallon per year ethanol plant would thus generate between 184-250 total jobs.

The total direct payroll for the ethanol facility and the feedstock collection, processing and transportation is estimated to be \$2,623,080. Total direct and indirect payroll is estimated to be \$4,884,240. Construction jobs are estimated at 88 jobs with a payroll of approximately \$2,000,000.

The ethanol plant's operations will have varying effects upon the road systems, depending upon the size and location of the plant and access road (e.g. interstate, state highway, paved county road, urban or rural setting). The primary initiators of road effects are the feedstock delivery to the plant and the subsequent shipping of ethanol and other products from the plant. Other major effects will be from the workers commuting to the operational plant as well as the short term construction activity to build the plant. The underlying traffic generator is the delivery of cellulose material to the plant.

An ethanol plant utilizing 240,000 BDT per year of forest biomass will require approximately 17,800 truckloads of biomass delivered to the facility annually. Assuming feedstock collection in the woods is limited to eight months out of the year and a six day per week, 12-hour per day delivery regime for the material, equates to 85 truckloads a day to the facility, seven truckloads per hour for a 12 hour day, or a truckload every eight and a half minutes. The *CEC Site Characterization Study* pointed out possible road limitations at Greenville and Loyalton.

#### IV. CONCLUSIONS AND RECOMMENDATIONS

Conversion of forest thinnings and timber harvest residues to ethanol and cogenerated electricity appears to be economically feasible at the five sites in the study that have an existing biomass power plant and other infrastructure available. Colocation with an existing biomass power plant is essential at this time.

The undeveloped or "greenfield" site in Greenville requires the installation of a boiler to provide steam to the ethanol process as well as buildings and other infrastructure that adds significantly to the total capital cost making this site less appealing at this time.

There appears to be an adequate supply of feedstock for one or more biomass to ethanol facilities in the Quincy feasibility study area.

The California reformulated gas (CA RFG) market is potentially a huge market for ethanol or ETBE (almost 1 billion gallons of oxygenate per year). However, ethanol is not currently used in California due to the 2% cap on oxygenate in CA RFG. Other West Coast markets such as Reno, Las Vegas and Phoenix are available, but are much smaller than the California market.

Forest biomass can be removed from the forest with acceptable impact to the environment and thinning the forest in the study area will improve the overall forest health and ecosystem balance.

Many technical, economic, and other assumptions have been made to perform the analyses reported in this study. Additional work is needed to prove or disprove these assumption and reduce the uncertainty of the results. The following *next steps* are recommended:

- Identify Potential Owner/Operators

Quincy Library Group will identify potential owners/operators of the ethanol manufacturing facility. This will entail reviewing the feasibility study with the current site owners to determine whether this project would fit into their own development plans. This task will also consist of discussions with current operators of ethanol manufacturing facilities (as well as other operators) to determine whether this new feedstock source (forest biomass) fits with their expansion plans.

- Secure Site Commitments

Quincy Library Group will solicit Letters of Intent from the site owners in this feasibility report (by the end of 1997) to quantify and qualify the general terms and conditions under which they would enter into the development phase of the project. QLG and NREL will also begin introducing prospective operators to the site owners and to ethanol technology purveyors.

- Long Term Supply Agreements

The delivered feedstock supply and price are the most sensitive economic factors in the feasibility study. QLG will investigate specific opportunities and seek the development of long term agreements on both public (particularly USDA Forest Service) and private lands.

- Design and Cost Estimates

A variety of further engineering and design tasks were identified for each of the three technologies studied. NREL will pursue partnerships and funding for these subsequent tasks.

## **V. TASK REPORTS**

The complete task reports follow. The task reports include:

*Feedstock Supply and Delivery Systems*

*Site Characterization Study*

*Biomass to Ethanol Facility Design, Cost Estimate, and Financial Evaluation*

*California Ethanol Market Assessment*

*Environmental Effects Report - Ethanol Feasibility Study*

*Northeastern California Ethanol Manufacturing Feasibility Study: Socioeconomic Report*

If you have downloaded the *Executive Summary* from the Internet and would like a copy of the complete report or any of the above task reports, please contact Sally Neufeld or Mark Yancey of the National Renewable Energy Laboratory at (303) 275-3000.